CHANGES IN SOIL INVERTEBRATE POPULATIONS CAUSED BY SOME ORGANOPHOSPHORUS INSECTICIDES

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Summary.

Results are given of the effect of the organophosphorus insecticides parathion, diazinon, phorate and disulfoton on soil invertebrates. Numbers of the animals and the biomass were decreased less than by aldrin and dieldrin. Numbers of parasitic mites were greatly lessened but, as in response to treatment with DDT, the numbers of springtails, trombidiform and oribatid mites often increased. The effects on these groups often remained longer than the residues of the insecticides. Only phorate lessened numbers of earthworms significantly. All four lessened numbers of pauropods. Beetles were affected only by parathion. No insecticide controlled symphylids economically.

INTRODUCTION

The partial ban of chlorinated hydrocarbon insecticides in England (M.A.A.F. Report 1964) has led to the greater use of organophosphorus, and, more recently, of carbamate insecticides to control soil-borne pests. Little attention has been paid to the possible effects of these less persistent compounds on invertebrates that are not pests. For example, the only significant effect of menazon at 2, 4 and 8 lb/acre was to lessen the numbers of onychiurid springtails (Collembola) (Raw 1965), and phorate and thionazin at 250 p.p.m. in the top 4 inches of soil killed almost all springtails, mites and earthworms (Way & Scopes 1965). Other information is scanty, and the present work aimed to study the effects of some commonly used organophosphorus insecticides on populations of soil invertebrates.

Methods

Four field experiments were done at four widely dispersed sites. Plots were taken at random. The insecticides tested, and the size of the plots, differed from site to site. The appropriate insecticide was sprayed on to the surface of each plot which was then rotovated in two directions as soon and as evenly as possible.

Four, two-inch diameter soil cores, six inches deep, were taken from each plot just before treatment, and at regular intervals afterwards. They were placed in screw-top aluminium cans and then placed in modified Tullgren funnels either during the same, or next day. The sieves above the funnels were six inches in diameter and each broken-up soil sample filled a sieve to a depth of two inches. The temperature above the soil sample was kept near 30°C., but the room was maintained at 20°C. to give a gradient through the soil of 10°C. Animals dropped into vials containing a mixture of 70% aqueous alcohol and 5% glycerol and were stored until sorted under a binocular microscope.

Numbers of earthworms and macroarthropods were estimated once at each site from three two-ft.sq. quadrats in each plot, by hand-sorting the top three to four inches in the field. The surface of the shallow pit was then levelled and a gallon of dilute formalin (25 cc in 1 gallon of water) poured on to it. All earthworms and macro-arthropods that came to the surface during the next fifteen minutes were removed and counted.

The sites and experimental details were as follows:

A. Bethersden (Vine Farm, Kent)
This site had been pasture for many years and bore wheat during the experiment. The soil was a heavy clay loam with a high water table and a large invertebrate fauna. Plots were 4 yards square in a random layout with one yard between plots. The insecticides were applied at the following rates:

a) Parathion; 8 lb a.i./acre
b) Diazinon; 8 lb a.i./acre
c) Disulfoton; 8 lb a.i./acre
d) Phorate; 4 lb a.i./acre

Soil samples were taken at approximately monthly intervals.

B. Sittingbourne (Woodstock Agricultural Research Centre, Kent)
A field that had been pasture for more than ten years was made available by courtesy of the Shell Chemical Co. The soil, a clay loam with flints, was ploughed in autumn, thoroughly cultivated and the insecticides applied soon after. The whole site was then planted to winter wheat. Plots were four yards square in a random layout with one yard between plots. The insecticides applied were:

a) Parathion; 4 lb a.i./acre
b) Diazinon; 4 lb a.i./acre

There was a very diverse fauna including many wireworms, earthworms and millipedes. Soil samples were taken at approximately monthly intervals.

C. Alton (Manor Farm, Hampshire)
The site was old pasture with very heavy clay subsoil, but well drained and covered with good clay loam surface soil. The whole site was planted with potatoes during the period of the experiment and soil samples were taken from the rows of plants. Plots were 20 feet x 10 feet. The insecticides used were:

a) Parathion; 4 lb a.i./acre
b) Diazinon; 4 lb a.i./acre

Soil samples were taken 4 weeks, 18 weeks and 24 weeks after treatment.

D. Harpenden (Highfield, Rothamsted, Herts.)
This had been a 300-year old pasture and had recently been ploughed. The soil was a silty loam with good texture in the top 6 inches. The plots were kept fallow for the period of the experiment and then grassed down. Plots were 8 feet x 9 feet. Of the insecticides applied the only one considered here is parathion at 4 lb a.i./acre. Soil samples were taken one month, four months and ten months after treatment.

RESULTS

The invertebrates were identified only to suborders and families. All results were analysed statistically and Table 1, which summarises the analyses of variance, shows that all treatments produced highly significant changes in numbers of animals, and that numbers changed significantly between sample dates. The interactions between

treatments and sampling dates were also highly significant. Space does not allow all the results to be given, so the more important are summarised in Tables 2, 3 and 4.

Table 2 summarises the changes in numbers of soil invertebrates averaged over all sampling dates. Each figure is the mean number of animals per soil core averaged over the whole sampling period, expressed as a percentage of the corresponding mean number for the untreated plots. Numbers in treated plots usually differed more from the untreated ones soon after treatment than later. The sum of all the means per sample for the different groups of invertebrates for a particular site and insecticide, expressed as a percentage of a similar total for the untreated control plots, gave the total percentage survival. Because such totals and percentages combine numbers of very small and very large invertebrates, it is best to express the results as the wet weight of animals, or, that is to say, the biomass. Biomass was estimated by multiplying the mean number for each group of invertebrates by the average weight for the group. Tables of such average weights are available (Edwards 1967). Mean biomasses were calculated for plots treated with each insecticide, for every site, and each group of animal, and the percentage change from the use of the insecticide was calculated.

The mean change in numbers of animals during the season does not give the whole picture, so the numbers in plots treated with insecticide, expressed as a percentage of numbers in control plots, when populations were at their peak, are summarised in Table 3. Peak populations, which depended on the particular group of animals, occurred at different times after the insecticides were applied but were usually in spring or autumn. Data expressed as above usually illustrate the maximum effect of the insecticide because numbers increase or decrease at different rates in treated and untreated soil.

The mean number per sample of each group of animals for every sampling date, and insecticide treatment, was plotted on graphs from which the time that the effects persisted, whether increases or decreases, were estimated (Table 4). None of the experiments lasted more than one year and effects still detected then are shown in the table as >52.

Table 1.

Summary of Analysis of Variance for experiments

Site	Insecticide	F		
		Treatment	Date	Treatment X Date
Bethersden	Diazinon	156.5**	72.2**	5.28**
	Disulfoton	176.0**	67.9**	4.02**
	Phorate	205.0**	37.6**	7.04**
	Parathion	282.5**	69.8**	7.07**
Woodstock	Diazinon	324.5**	168.0**	4.91**
	Parathion	143.0**	100.0**	13.23**
Alton	Diazinon	107.3**	48.8**	4.18**
	Parathion	98.7**	63.2**	5.21**
Highfield	Parathion	86.5**	32.3**	3.87**

Table 2

Percentage survival averaged from all sampling dates over one year after insecticide treatment.

Insecticide	Parathion				Diazinon			Phorate	Disulfoton
Site / Animal Group	A	B	C	D	A	B	C	A	A
Earthworms	96.3	96.0	83.0	-	73.9	108.1	100.0	21.4	70.0
Symphylids	79.5	61.4	34.8	92.5	46.5	78.6	-	58.2	110.0
Pauropods	3.0	18.2	20.0	82.4	5.0	26.7	4.0	21.0	3.0
Parasitic Mites	25.0	38.2	77.5	49.1	52.8	39.0	69.8	62.1	41.1
Trombidiform Mites	47.2	34.8	265.0	125.0	26.6	41.3	282.0	62.3	87.5
Oribatid Mites	69.5	145.0	213.0	66.4	87.5	68.0	167.6	39.0	55.2
Surface-Living springtails	67.7	80.5	207.0	78.8	46.9	72.0	80.0	42.5	17.9
Deep Soil-Living springtails	48.8	58.2	301.5	145.6	136.0	33.1	102.4	72.2	69.7
Fly Larvae	34.4	80.2	23.3	38.6	27.9	53.3	51.7	21.4	41.4
Beetles	59.6	49.2	43.5	90.8	91.0	90.3	71.4	84.5	86.0
Total % Survival (Numbers)	53.7	72.8	166.8	94.0	74.0	70.5	104.8	52.4	49.5
Total % Survival (Biomass)	52.4	91.2	117.7	83.5	44.8	58.7	92.1	46.5	44.6

Table 3

Numbers of animals expressed as percentage of control at peak population

Insecticide	Barathion				Diazinon			Phorate	Disulfoton
Site / Animal Group	A	B	C	D	A	B	C	A	A
Symphylids	50.0	26.6	-	37.8	50.2	87.6	-	40.0	30.1
Pauropods	2.1	11.1	-	7.1	3.8	16.5	-	36.8	7.2
Parasitic Mites	32.2	19.2	18.1	64.3	41.6	20.8	24.4	51.0	60,0
Trombidiform Mites	13.3	18.6	444.0	135.0	19.2	46.6	334.0	50.0	65.0
Oribatid Mites	42.5	336.2	201.0	57.2	262.0	60.2	179.0	31.2	137.2
Surface-living springtails	48.8	57.3	392.0	35.1	52.6	53.5	268.0	43.3	34.4
Deep-living springtails	33.9	63.7	267.8	174.0	194.5	49.6	109.8	29.2	171.0
Fly larvae	7.8	59.8	7.7	34.0	7.2	35.2	32.6	31.4	33.1
Beetles	5.2	28.0	21.4	25.0	36.3	39.2	36.8	40.7	43.8

Table 4

Minimum time for effects of insecticide to disappear (weeks)

Insecticide	Parathion				Diazinon			Phorate	Disulfoton
Site	A	B	C	D	A	B	C	A	A
Time for insecticide 50% to disappear 95%		6 weeks 26 weeks				9 weeks 37 weeks			
Symphylids	16	10	18	16	16	10	18	14	12
Pauropods	>52	>52	-	40	>52	>52	-	>52	>52
Millipedes	-	>52	-	40	-	>52	-	-	-
Centipedes	-	20	-	40	-	>52	-	-	-
Parasitic Mites	50	45	28	41	37	43	32	38	39
Trombidiform Mites	35	>52	>52	>52	40	>52	>52	34	34
Oribatid Mites	42	>52	>52	40	>52	48	28	39	52
Deep-living springtails	36	50	>52	>52	>52	>52	>52	34	>52
Surface-living springtails	41	36	>52	32	38	36	>52	40	44
Fly larvae	21	18	22	36	38	25	25	42	38
Beetles	20	12	19	16	16	12	24	12	8

DISCUSSION

The four organophosphorus insecticides did not lessen numbers of soil invertebrates as much as did aldrin and dieldrin (Edwards 1965a, 1965b, 1967). The invertebrates most susceptible to the chlorinated hydrocarbons are pauropods (Pauropoda), isotomid springtails and fly larvae (Diptera). Pauropods are also easily killed by organophosphorus insecticides (Table 2); fly larvae are killed less easily. The surface-dwelling springtails (Isotomidae, Entomobryidae) seem to be more resistant to organophosphorus insecticides than to the chlorinated hydrocarbons. The parasitic mites (Gamasina), not very easily killed by the chlorinated hydrocarbons except DDT, are more easily killed by the organophosphorus insecticides. Symphylids seemed to be a little more susceptible to organophosphorus insecticides than to chlorinated hydrocarbons, but the differences were small and transient. The response of springtails, trombidiform and oribatid mites to organophosphorus insecticides varied (Tables 2 and 3), and often resembled the response of springtails to DDT, which greatly lessened numbers of parasitic mites and increased numbers of springtails. This also happened occasionally with lindane but with none of the other chlorinated hydrocarbons (Sheals 1956; Edwards, Dennis and Empson 1967). Oribatid mites, entombryid and onychurid collembola also increased in plots treated with chlorfenvinphos (Edwards, Thompson and Beynon 1967). Our experiments show that the insecticides cause these invertebrate groups to increase in numbers almost as often as to decrease. These increases are so similar to those found with DDT that it is reasonable to suspect that they are caused by killing parasitic mites, or other predators (Edwards, Dennis and Empson 1967). Beetles (Coleoptera), both adults and larvae, are less susceptible to the organophosphorus insecticides but different species differ greatly in their susceptibility.

Parathion and diazinon do not persist long in soil (Table 4), but their effects can last longer than the residues. The effects were least on symphylids, fly larvae and beetle adults and larvae, and lasted little longer than the life of the chemical. For all the groups of animals mean numbers in treated plots often differed significantly from those in untreated plots even after one year. When an insecticide increased numbers of a particular group, the effect usually lasted longer than did concomitant decreases in other groups (Table 4), probably because of the lag of a month or more after the insecticide is applied, before numbers begin to increase. If the increase occurred soon after applying the insecticide, some stimulating cause rather than death of predators could be postulated.

There were few outstanding differences between the four insecticides. Over the whole season, never more than 50 per cent of the animals were killed, and parathion and diazinon increased the total numbers at the Alton site. Changes in biomass did not differ greatly from changes in numbers. Similar results were obtained with chlorfenvinphos in four experiments (Edwards, Thompson and Beynon 1967). Only phorate, applied at 4 lb a.i./acre, lessened numbers of earthworms significantly. Experiments other than those described here have confirmed that phorate is very toxic to earthworms. No insecticide controlled symphylids economically, even though parathion and diazinon are recommended. All four insecticides easily killed pauropods but parasitic mites and fly larvae were killed variably though all insecticides considerably lessened their numbers. Numbers of beetles were not much lessened by any of the insecticides except parathion.

These organophosphates, which are becoming commonly used, do not

seriously alter populations of soil invertebrates, and beyond the season of application may either increase or decrease numbers. Most of the pests formerly treated with persistent insecticides can now be controlled with these less persistent ones.

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